Combining Good Practices

Method to Study Introductory Physics in Engineering Education

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INTRODUCTION

During the last two decades, entry-level engineering students' basic abilities in Mathematics and Physics – the basis of engineering education - have decreased dramatically. To meet the challenge to educate professional bachelor level engineers with sufficient natural-scientific background, effective education methods are needed. Physics education research and engineering education research have developed a plenty of good practices to enhance the students' learning outcomes. Combining practices together introduces new method to study introductory physics in the Tampere University of Applied Sciences.

1 DIFFICULTIES AND GOOD PRACTICES

1.1 A challenge to meet

The term "engineer" has slightly different interpretations in Europe. In general, an engineer is a person who is highly educated to meet technological challenges and to find innovative solutions. The focus of know-how is on the technological problem-solving skills, but the underpinnings of the engineering lie on the strong mathematical and natural-scientific background. Among other important learning outcomes, according to EUR-ACE® framework standards, a first cycle graduate should have the

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knowledge and understanding of the scientific and mathematical principles underlying their branch of engineering [1].

The role of the physics in the engineering education is to fulfil the need of the natural scientific background as well as to introduce the method of natural-scientific problem-solving. Nowadays this is a challenge at least in Tampere University of Applied Sciences. Even though students' socio-economic background isn't an issue in Finland, the first year students are heterogeneous in other ways: in terms of mathematical and natural-scientific background. Some students seem to have a strong lack of interest in mathematics and physics. Feedback from some physics courses show that a part of the students expect that they do not need physics skills to become engineers. Some of the first year students are not used to be active learners. They expect teacher to teach and imagine that they learn by passively listening to the teacher. To present an overall picture of the mathematical and natural-scientific skills of a first year student, data from the entrance examination is presented in *Fig. 1*. There were 2721 applicants of which 1890 arrived to the examination.

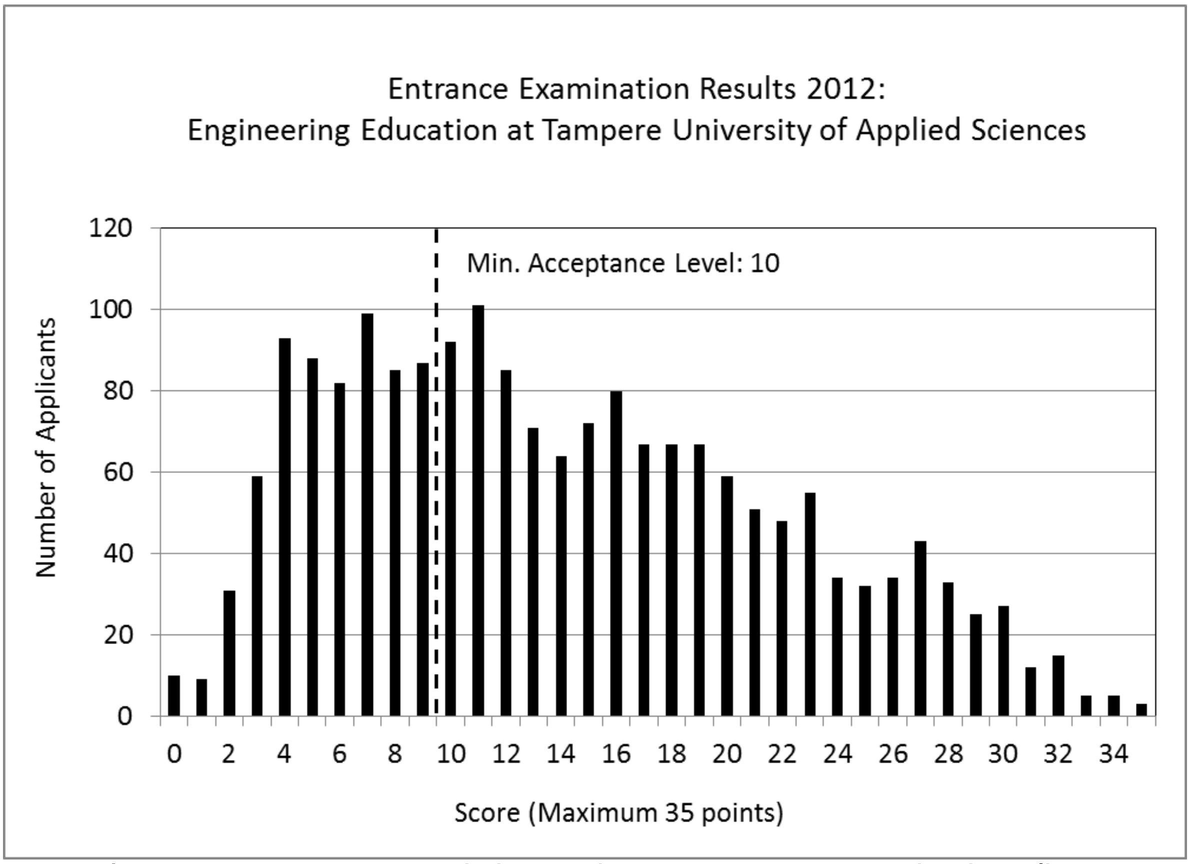

Fig. 1. Entrance-exam statistics, spring 2012, *N* = 1890 arrived applicants

Figure 1. shows that only 46 % of the all 2721 applicants get enough points in the entrance examination, to qualify as capable to enter the studies. 30 % of the applicants do not arrive to the examination at all, 24 % of the applicants do arrive, but do not get enough points to qualify, even though the requirement is very low, only 10 points out of 35. Annual intake of engineering students in Tampere University of Applied Sciences is about 600.

Entrance examination test, among others, basic skills in mathematical problem-solving and basic laws in physics. Two examples of entrance examination questions translated in English are presented below.

I) *Solve the equation:* $$3\left(\frac{x^2}{2}+1\right)+4x-x^2=\frac{x^2}{2}+\frac{x}{2}+5$$

II) *A satellite has a rocket propulsion system, which produces* 0.070 N *thrust.*
   a) *What is the maximum mass of the satellite, if it should gain the acceleration of* 0.20 mm/s^2*?*
   b) *The speed of the satellite is increased with the acceleration of* 0.20 mm/s^2 *for 80 days and nights. What is the final speed the satellite gets in* km/h*?*

In order to educate professional engineers the challenge is not only physics challenge, but a challenge of the engineering education in general. Introductory physics, studied during the first two years has the key role to raise enthusiasm concerning engineering studies. Effective education with strong underpinnings during the first years could reduce the amount of dropouts, which is relatively high in Tampere University of Applied Sciences. In youth education there were 488 graduated bachelor-level engineers in 2012, while annual intake is about 600 students.

1.2 Good practices

The good reported practices we have chosen to tackle the challenges are:

1. Interactive engagement
2. Peer education
3. Interactive lecture demonstrations
4. Tutorials
5. Pre-lecture assignments
6. The use of video and multimedia content
7. Data logger -based measurements

Interactive engagement classes achieve better learning outcomes compared to the traditional classes, especially if a correct qualitative level understanding is measured. Hake's survey of 6000 students [2], show that students on the interactive classes got significantly better scores on the Force Concept Inventory [3], than students on the traditional classes.

The active engagement can be raised using peer education, the pedagogical method in which students interact in cycles explaining core concepts to other students. A method may vary depending on the instructor, but generally after the short presentation, the instructor gives students a conceptual, often a multiple choice question, in which students first give an individual answer, which is reported to the instructor. After that students discuss their answers in small groups aiming to convince the fellow students about the correctness of their own answer. This requires explaining their reasoning, which makes them more aware of their own thinking. After discussion the answer is asked or polled again. The use of modern educational equipment, the audience response systems (“clickers”) helps the collection and presentation of the answer data. [4] The method of peer education supported by clickers was used in teaching engineering dynamics. Students performed in the same level in computational problems, but achieved better conceptual understanding compared to traditional method [5].

“Interactive lecture demonstrations” is similar method to peer education, except it always includes a demonstration, with or without microcomputer based laboratory (MBL) system. The method includes demonstration, an individual prediction of what will happen, a group discussion with a final prediction prepared in a group, a demonstration with a possible MBL measurement and a group discussion of interpreting what really happened. [6] Similar methods without audience response system has been used earlier in Tampere University of Applied Sciences [7] [8], but the implementation using papers instead of “clickers”, was too time consuming.

Tutorials in physics teaching are short conceptual sessions in small groups usually before lectures. The working system is often similar to peer instruction, but implementations vary. The idea is to use the contact time between instructor and the students effectively and start the conceptual process before the lectures. The conceptual process can also be ignited with tutorial video clips [9] or different kind of pre-lecture activities like textbook reading assignments or use of multimedia modules [10].

The video content can be used in several different ways. The use of tutorial video clips [9] reduced the number of frequently asked questions. The video material can be used as routine-like material or extra material for heterogeneous groups. The video material can also be used in combining theory into practice with digital video analysis [11]. Especially in mechanics courses, a movement of an object can be traced using video analysis software. The method of video analysis is reported to raise the motivation of the students, and improved their understanding of natural-scientific principles more deeply than traditional methods [12] [13].

2 PHYSICS STUDIES NOW AND THE NEW METHOD

2.1 Studies now and in the new curricula 2013

Current method to study physics in Tampere University of Applied Sciences is quite traditional, consisting of lectures, lecture demonstrations, examples, possible pre-lecture homework, traditional homework and exams. Methods vary slightly among lecturers. Physics laboratory work forms two separate courses. The new method is piloted in the introductory mechanics course in autumn 2013 and is later applied in the other physics courses. Physics courses in curricula 2012 – 2013 and 2013 – 2014 are presented in *Table 1*.

Table 1. Physics courses 2012 – 2013 and 2013 - 2014

2012 – 2013	2013 - 1014
Mechanics 1 (2 cr)	Mechanics (3 cr)
Mechanics 2 and Thermophysics (3 cr)	Fluid Mechanics and Thermophysics (3 cr)
Electrostatics and Magnetism (3 cr)	Electrostatics and Electric Circuits, Magnetism (3 cr)
Oscillation and Waves, Atom and Nuclear Physics (3 cr)	Oscillations and Wave Mechanics, Atom and Nuclear Physics (3 cr)
Physics Lab. 1 (2 cr)	Basics of Measuring and Reporting (3 cr)
Physics Lab. 2 (2 cr)	Laboratory Works of Physics (3 cr)

2.2 The new method

The basic difficulty in studying introductory engineering physics has been the ability to understand the connection between the real-life concrete situation and the abstract symbolic world of quantities with relations between them. Nowadays some problems occur even in basic quantitative predictions and calculations. The key to the situation is to encourage students to take more responsibility from their own learning and improve their motivation to engineering physics studies. The schedule system of the study method is presented in the *Fig. 2*.

Time	Mon	Tue	Wed	Thu	Fri
8-9					
9-10		Conceptual			
10-11		Lecture			Tutorial / Assign.
11-12		Lecture			Exc. / Meas.
12-13			Excercise		Exc. / Meas.
13-14			Excercise		Week Test / Meas. Results
14-15					
15-16					

(shaded box)	Teacher present, other times are for students only.
Excercise	Students are solving computational assignments in groups.
Exc.	Students are preparing for the week test in groups.
Meas.	Students are carrying out measurement tasks in groups.
Week Test	Students answer to the week test problmes individually.
Meas. Results	Students present results and learning outcomes of the measurement tasks in groups.

Fig. 2. An exemplary week schedule of the study method

To enhance learning outcomes, a special effort is first applied to create correct qualitative-level understanding of the phenomena, the meanings of quantities and the physical laws. The plan is to introduce any new subject matter with a series of conceptual questions using demonstrations interactively with peer education. Audience response system ("clickers") is used to get responses quickly. Some of the subjects are underpinned beforehand with a series of qualitative-level pre-lecture assignments.

After the qualitative understanding, studying continues with traditional quantitative calculations and quantitative-level problems. Routine-like calculations and some extra examples are introduced using video-content. Instead of reviewing students' homework during classroom teaching, they can check their own solution and study the correct methods by watching and listening teacher doing the calculations on video. In this way, valuable contact time is saved from routines to those subjects that students find most challenging. Some simple measurement tasks are used to combine the qualitative-level understanding with quantitative-level calculations. The plan is to use simple traditional measurements, videos with video-analysis software and data loggers. For every 2 weeks a short ½ - 1 hour exam is carried out

Students are planned to be shared to groups of 4-5 to be used both at the measurement tasks as well as during independent study time. The group is responsible for outcome of measurement task and for helping each other during autonomous exercise sessions. By grouping the freshmen, it is hopefully possible to enhance their commitment to their studies.

2.3 Assessment

Final grade is formed from week-exams, measurement tasks and the final exam. The weights of the different types of assessed tasks are shown in *Table 2*. By using week exams, it is possible to change the balance of assessment from summative towards formative assessment and thus the teacher has more knowledge to guide the students during learning process.

Table 2. Assessment in the new method

Week	Task	Weight
1.	Measurement	5 %
2.	Week exam	10 %
3.	Measurement	5 %
4.	Week exam	10 %
5.	Measurement	10 %
6.	Week exam	10 %
7.	Final Examination	50 %
	Total:	100 %

2.4 Implementation and further development

The new method is implemented in autumn 2013 with four different student groups in the introductory mechanics course. The results will be reported after the first implementation. If this method is found effective, it will be applied later on the other physics courses in Tampere University of Applied Sciences.

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